QUANTIFYING ASYNCHRONOUS BEHAVIOR IN SUSTAINABLE FUEL COMBUSTION EXPERIMENTS

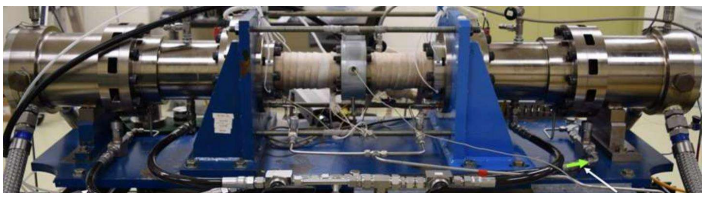
Andrew Park, S. Scott Goldsborough, Transportation and Power Systems Division

MOTIVATION

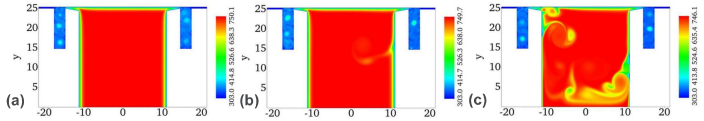
Sustainable fuel research is helping transition the transportation industry to no longer rely on finite resources for fuel sources but instead turn to more renewable alternatives. To replace petroleum-based fuels, sustainable fuels must have similar combustion properties, often measured in a rapid compression machine, which requires a quiescent environment for accurate investigations. However, asynchronous behavior in dual-piston rapid compression machines (dpRCMs) can cause serious degradation of the adiabatic core and undesirable results.

OBJECTIVES

- Accurately identify the delay time in dpRCM experiments
- Compare against linear variable differential transformer (LVDT) data



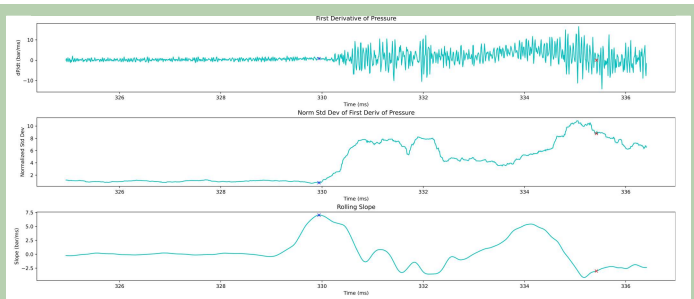
Dual-piston rapid compression machine (dpRCM)



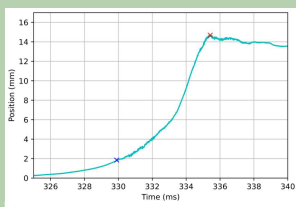
Simulated temperature distribution within reaction chamber at delay times of (a) 4ms; (b) 6ms; and (c) 8ms.

METHODS

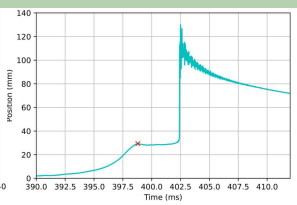
- Delay in piston actuation – difference in stroke completion times
- Identifying beginning and end of asynch
  - Beginning – sharp increase in noise
    - First piston striking reaction chamber
    - Dramatic increase in normalized standard deviation of first derivative
  - End – end of compression
- Improved from threshold-based algorithm to rolling slope-based
  - Avoiding falsely identifying noise
  - Difference between two points held at constant offset



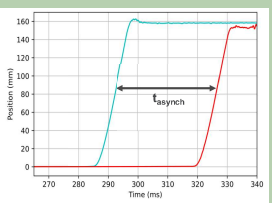
Start of noise in first derivative coinciding with dramatic increase in normalized standard deviation of first derivative also coinciding with extrema in the rolling slope trace. Dataset 2019-0429.0009.



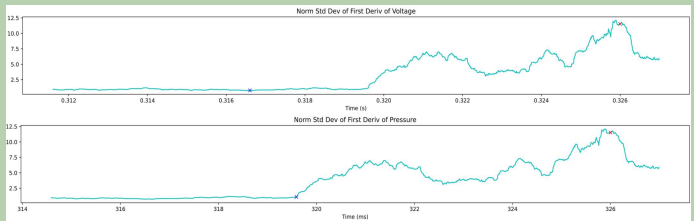
Start of asynch and end of compression for non-reactive dataset 2019-0429.0009



End of compression for reactive dataset 2019-0503.0022

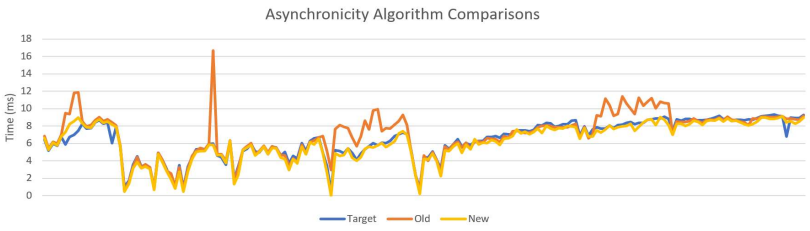


Overlaid LVDT curves showing asynch time calculations



Previous algorithm identification of start of asynch (top) and new identification of asynch (bottom) for dataset 2019-0429,0006

RESULTS



Old and new asynch algorithms overlaid onto LVDT data

	Old	New
Mean Difference (ms)	0.460	0.048
Standard Deviation (ms)	1.264	0.224
# of Outliers	46	6

Safety Note: *When working with digital information, following all cybersecurity and counterintelligence procedures is imperative. This includes but is not limited to creating strong passwords, logging out of all devices, and not accessing files or data with personal accounts.*

IMPACT

- Asynchronous behavior affects combustion properties
- Accurately determining delay times gives information regarding inconsistencies in results and machine diagnostics
- Reliable method of testing system improvements
- Greater understanding regarding the effects of asynchronous behavior and combustion dynamics
- Eliminates the need for LVDT data on all experiments

FUTURE DIRECTIONS

- Apply the script to all trials and map the effects
- Test changes made to the system to gauge efficacy
- Integrate algorithm into LabVIEW for direct processing
- Extract additional data from the pressure trace
  - Total compression time
  - Ignition delay time

References:

[1] S. Scott Goldsborough, Song Cheng, Dongil Kang, Joseph P. Molnar, Yuri M. Wright, Christos E. Frouzakis. Asynchronicity in opposed-piston RCMs: Does it matter?, *Proceedings of the Combustion Institute*.

U.S. DEPARTMENT OF ENERGY

Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC.

Argonne NATIONAL LABORATORY